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विद्युत प्रयोजनों के लिए सेल्युलोजिक कागज़

भाग 2 परीक्षा पद्धति

(पहला पुनरीक्षण)

Indian Standard

CELLULOSIC PAPERS FOR ELECTRICAL PURPOSES

PART 2 METHODS OF TEST

(First Revision)

ICS 29.035.10

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 1998

Price Group 12

Solid Electrical Insulating Materials Sectional Committee, ET 02

NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 554-2 (1977) 'Specification for cellulosic papers for electrical purposes — Part 2 : Methods of test' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Solid Electrical Insulating Materials Sectional Committee (ETD 02) and approval of the Electrotechnical Division Council.

This standard (Part 2) is one of the series of Indian Standards which deal with cellulosic papers for electrical purposes This series consists of the following parts·

Part 1 Definitions and general requirements

Part 2 Methods of test

Part 3 Individual materials — Specification

This standard (Part 2) contains the test methods to be used in testing cellulosic papers for electrical purposes to meet the requirements prescribed in the various sections of Part 3

This revision has been undertaken to align this standard with IEC 554-2 (1977).

Certain conventions, however, are not identical to those used in Indian Standards. Attention is particularly drawn to the following·

a) Wherever the words 'International Standard' appears, referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point ( ) as the decimal marker

Corrigendum and Amendments 1, 2 and 3 issued to IEC Pub 554-2 (1977) have been printed at the end.

Only the English language text in the IEC standard has been retained while adopting it in this Indian Standard

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2·1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard

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IS 9335 (Part 2) : 1998
IEC Pub 554-2 (1977)

Indian Standard
CELLULOSIC PAPERS FOR ELECTRICAL PURPOSES
PART 2 METHODS OF TEST
(First Revision)

INTRODUCTION AND SCOPE

This standard is one of a series which deals with insulating cellulosic papers.

The series will have three parts:

Part 1: Definitions and general requirements.

Part 2: Methods of test.

Part 3: Specifications for individual materials.

This Part 2 of the standard contains the test methods to be used in testing cellulosic papers for electrical purposes to meet the requirements prescribed in the specification sheets of Part 3.

1. General notes on tests

1.1 In this standard, reference is made in several places to ISO publications accompanied by a short description of the method used. It is to be understood that this short description is meant for identification purposes only and that all details should be taken from the ISO publication itself.

1.2 In this standard, the definitions of "specimen" and "test piece" as defined in ISO Recommendation R 186 are used.

Specimen: A rectangle of paper or board cut to given dimensions from sheets drawn from selected units.

Test piece: The quantity of paper or board on which the determination is carried out in accordance with the method of test. It may be taken from a specimen; in some instances it may be the specimen itself.

1.3 Unless otherwise specified, the specimen, after being cut, shall be conditioned for not less than 16 h in an atmosphere of 23 ± 2 °C and 50 ± 5% r.h. Test pieces are cut from the specimen and tested in this atmosphere.

In case of dispute the conditioning atmosphere shall be 23 ± 1 °C and 50 ± 2% r.h and shall be approached from the dry side (after drying at 70 °C to a moisture content less than 4%).

1.4 Unless otherwise specified, the number of specimens shall be three.

2. Thickness

Thickness shall be measured either in accordance with ISO Recommendation R 534 or, for thin papers, in accordance with ISO Recommendation R 438, in each case with the exceptions given below

2.1 *ISO Recommendation R 534: Determination of the thickness of single sheets of paper*

Principle

The method is based on the use of a precision dial micrometer to measure the thickness of a single sheet when a static load is applied.

Exceptions

The test shall be carried out on three conditioned test pieces, one determination being made on each of the three test pieces.

Reporting of the standard deviation is optional.

The central value is taken as the result, the two others are reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

2.2 *ISO Recommendation R 438 Method for the determination of the bulking thickness and bulk of paper*

Principle

The method is based on the use of a precision dial micrometer to measure the thickness of a stack composed of a minimum of five sheets.

Exceptions

The test shall be carried out on three conditioned specimens, each composed of five sheets.

For narrow width material where the width is less than the stipulated 250 mm, the five measurements on each stack shall be made at approximately equal intervals on a specimen 400 mm in length

The central value is taken as the result, the two others being reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

3 Substance (mass per square metre, basic weight or grammage)

Paper grammage shall be measured according to the method described in ISO Standard 536: Paper and board — Determination of grammage, with the following exceptions:

- Clauses 5 and 6 of ISO Standard 536 are ignored.
- The test shall be carried out on three conditioned test pieces, one determination is made on each of the three test pieces.
- The mass is to be determined to an accuracy of 0 5% on conditioned test pieces of not less than 500 cm².
- The central value is taken as the result, the two others being reported

Principle

The area of each test piece and its mass are measured and the mass per square metre is calculated, all measurements being made on conditioned test pieces.

Where grammage is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

4. Apparent density

The thickness and grammage are determined on each of three test pieces in accordance with Clauses 2 and 3. For each test piece the apparent density is calculated and the central value of these three densities taken as the result, the two others are reported. The apparent density is expressed in grams per cubic centimetre.

5 Tensile strength and elongation

Tensile strength and elongation shall be measured according to the method described in ISO Standard 1924, Paper and board — Determination of the tensile strength, with the following exceptions:

- Nine measurements are made on test pieces cut from both the machine direction and the cross direction.
- The central value of the test pieces, in each direction, is taken as the result and the highest and the lowest values in each direction are reported
- Alternatively, the results can be expressed as breaking length in metres to the nearest 100 m.

Principle

Measurement of the tensile force required to cause failure of test pieces 15 mm by approximately 250 mm, cut from both directions of the paper, when applied under standard test conditions.

6 Internal tearing resistance

Internal tearing resistance shall be measured according to the method described in ISO Standard 1974: Paper — Determination of tearing resistance. The single tear tester shall be used with the following exceptions

Nine measurements are made on test pieces cut from both the machine direction and the cross direction

- The central value of the test pieces, in each direction, is taken as the result and the highest and the lowest values in each direction are reported.

Principle

Rectangular test pieces having a single cut leaving 43 mm length to be torn and measuring the energy required to tear this.

7. Edge tearing resistance

7.1 *Test apparatus*

An edge tear stirrup (see Figure 1, page 24) shall be used, attached to the tensile testing apparatus as described in Clause 5. The edge tear stirrup consists of a thin steel plate (A) which forms a horizontal plate supported on edge by the ends of a stirrup-shaped frame.

The thin metal tang of the stirrup frame is fastened in the lower clamp of the tension testing machine, so that the vertical centre line of the stirrup coincides with the line connecting the midpoints of the upper and lower clamps. The horizontal plate is removable from the stirrup frame and two plates of different thickness are supplied for use with papers of different thickness ranges. One plate has a thickness of 1.25 ± 0.05 mm and one plate a thickness of 2.50 ± 0.05 mm. The edge of the plate forms a shallow V-notch, the sides of which subtend an angle of 150 ± 1°. The sides of the V-notch are semicircular in cross-section and shall be smooth and straight.

7.2 *Test pieces*

Nine test pieces shall be cut in the machine direction and nine in the cross direction of the paper, 15 mm to 25 mm in width and not less than 250 mm in length.

The test pieces shall be conditioned according to Sub-clause 1.3.

7.3 *Procedure*

Attach a plate of the proper thickness to the stirrup frame. The plate with the thickness of 1.25 ± 0.05 mm is to be used for papers of up to 0.75 mm in thickness and the plate with the thickness of 2.50 ± 0.05 mm for thicker papers.

Fasten the thin tang of the stirrup in the lower clamp (see note) of the tension-testing machine so that the vertical centre line of the stirrup coincides with the line connecting the mid-points of the upper and lower clamps of the testing machine, and so that the sides of the V-notch are symmetrically located with the line through the mid-points of the clamps.

Note. — The stirrup may be fastened in the upper clamp, if desired. This procedure will require rebalancing the tension-testing machine to compensate for the mass of the stirrup.

Place the lower clamp of the machine so that the lower edge of the upper clamp is about 90 mm above the V-notched plate

Thread the test piece through the stirrup, under the plate, and bring the two ends together and fasten them in the upper clamp.

In this operation, most of the slack in the test piece is taken up, but care shall be exercised not to apply a tearing force to the test piece. Make the application of the first increments of load to the test piece very slowly if possible, to minimize abnormal strains due to inertia effects. Increase the load so that tearing starts in 5 s to 15 s and record this load in kilograms.

7.4 *Results*

Report the central values for each of the two directions of the paper in newtons, mentioning the thickness of the plate used, the rate of loading and the width and thickness of the test pieces.

8. Bursting strength

The bursting strength shall be determined according to the method described in ISO Standard 2758: Paper — Determination of bursting strength, with the following exceptions:

– The test pieces shall be conditioned in accordance with Sub-clause 1.3.

– The central value shall be taken as the result; the highest and lowest values shall be reported

Principle

A test piece, placed in contact with a circular elastic diaphragm, is rigidly clamped at the periphery but free to bulge with the diaphragm. Hydraulic fluid is pumped at a constant rate, bulging the diaphragm until the test piece ruptures The bursting strength of the test piece is the maximum value of the applied hydraulic pressure

9. Folding endurance

9.1 *Test apparatus*

A folding tester (Schopper type).

9.2 *Test pieces*

Nine strips 15 mm wide, cut in the machine direction, and nine other strips cut in the cross direction.

9.3 *Procedure*

Clamp the specimen in both clamps Apply a tension of 5 N with specimens up to 0 03 mm in thickness and a tension of 10 N with thicker specimens. Determine the number of double folds which the paper withstands, applying a plate of 0 5 mm in thickness with a radius of curvature of 0 25 mm, at a speed of 100 to 200 double folds per minute.

9.4 *Results*

Report the central value of each series to two significant figures. The highest and lowest values shall also be reported.

10. Moisture content

Moisture content of paper, as received, shall be measured according to the method described in ISO Recommendation R 287· Paper — Method for the determination of moisture content of paper (oven-drying method) The result should be expressed as percentage moisture of the original mass. Three test specimens shall be taken from the reel according to Sub-clause 6 2 3 of ISO Recommendation 287 The central value obtained is taken as the result; the highest and lowest values are reported

Principle

Weigh the test piece at the time of sampling and again after drying in an oven at 102 °C to 105 °C to constant mass.

11. Ash

The amount of residue of paper left after incineration shall be determined according to the method described in ISO Standard 2144: Paper and board — Determination of ash.

Three determinations shall be made. The result should be expressed as a percentage of the oven dry mass. Report the central value obtained as the result; the highest and lowest values are reported.

12. Conductivity of aqueous extract

12.1 *Test apparatus*

- A conductivity cell with known cell constant K.
- A measuring instrument, capable of measuring conductance or admittance to a minimum reading of 1 μS with an accuracy of 5%, in the frequency range 50 Hz to 3 000 Hz. Alternatively, the resistance may be measured with the same accuracy.
- Wide-mouth 250 cm^3 conical flasks with reflux condensors in acid- and alkali-resistant glass.

12.2 *Procedure*

The determination is to be made on the material as received. One measurement shall be made on each of three extractions. First, a blank test shall be carried out on water which has been boiled for 60 ± 5 min in the flask to be used. If the conductivity of that water is not more than 200 μS/m, the flask may be used. If the conductivity is more than this value, then the flask shall be boiled with a fresh portion of water. If the conductivity of the second test exceeds 200 μS/m then, another flask shall be used.

The test on the paper shall then be carried out as follows:

Cut a test specimen weighing approximately 20 g into pieces of about 10 mm × 10 mm. Weigh 5 g into a 250 cm^3 glass flask with a reflux condenser and add 100 cm^3 water having a conductivity of not more than 200 μS/m. The water shall be boiled gently for 60 ± 5 min, and then cooled in the flask to room temperature. It is necessary to take precautions against the absorption of carbon dioxide from the air.

The extract is then decanted into the measuring vessel for the conductivity to be measured immediately. *The measuring vessel shall be rinsed twice with the extract. The measurement of the conductivity shall be* made at 23 ± 0.5 °C.

Notes 1. — Extraction in accordance with Method 1 of Clause 14 is an acceptable alternative, but using 5 g in 100 cm^3.

2. — It is essential to ensure during the taking, storing and manipulation of specimens and test portions intended for test for conductivity, pH and chloride content of aqueous extract, that they are not contaminated either by the atmosphere, particularly the atmosphere of a chemical laboratory, or by handling with bare hands

12.3 *Results*

Calculate the conductivity of the extract solution as follows

$$\gamma = K (G_1 - G_2)$$

where:

γ = conductivity of extract solution, expressed in microsiemens per metre

K = cell constant, expressed in m^{-1}

G_1 = conductance of extract solution, expressed in microsiemens

G_2 = conductance of blank, expressed in microsiemens

Report the central value as the result; the highest and lowest values are reported.

13. pH of aqueous extract

13.1 *Test apparatus*

- — A pH-meter with glass and calomel electrodes having a sensitivity of at least 0.05 pH units.
- — Wide-mouth 250 cm^3 conical flasks in acid- and alkali-resistant glass.

13.2 *Procedure*

One measurement shall be made on each of three extractions.

Prepare an extract as described in Sub-clause 12.2.

The extract shall be decanted only for immediate use, avoiding unnecessary exposure to the atmosphere. Calibrate the pH-meter with a buffer solution having a pH value within ±2 pH units of that of the extract. Remove the electrodes from the buffer solution and wash them well by rinsing several times in distilled water and once in a small quantity of extract.

Immerse the electrodes in the unfiltered extract and measure the pH value of the extract at 23 ± 2 °C

Notes 1. — If the extract is to be used for the determination of conductivity, the sample for this determination should be drawn from the aqueous extract prior to the pH determination This is because potassium chloride, which diffuses from the calomel electrode, would otherwise affect the result.

2. — See Note 2 of Sub-clause 12.2.

13.3 *Results*

Report the central value as the result; the highest and lowest values are reported.

14. Chloride content of aqueous extract

Method I

14.1 *Precautions*

All apparatus for use in this test must be scrupulously clean. It is suggested that all flasks, beakers and funnels be boiled in de-ionized water after normal cleaning and rinsing Handling of apparatus should be by stainless steel tongs Similarly, forceps and scissors for sample preparation should be of stainless steel and kept clean in the same way.

Note. — See also Note 2 of Sub-clause 12 2.

14.2 *Test apparatus*

A measuring device capable of measuring a d c. voltage in the range 0 to 300 mV with an accuracy of 2 mV (e.g. an electronic voltmeter or potentiometer such as a pH-meter).

A 600 cm^3 flat-bottom high-grade resistance glass or quartz flask.

Steam bath.

Analytical balance.

Glass micrometer syringe (Method 1 only).

Microburette graduated in 0.01 cm^3 divisions (Method 2 only).

Magnetic stirring device.

Measuring cylinders, beakers, filter funnels, rods and needles, etc.

Fast-grade filter papers.

14.3 *Procedure*

One determination shall be made on each of three extractions. For each extraction, the paper shall be cut into strips approximately 50 mm × 10 mm. A mass of approximately 20 g shall be placed in a 600 cm^3 flat-bottom flask and 300 cm^3 of boiling de-ionized or distilled water added, which fulfils the conductivity requirements of Clause 12.

The mixture shall be kept on a steam bath for 60 min, the mouth of the flask being covered by a loosely fitting beaker over the neck.

The suspension shall then be filtered using suction through a pre-extracted filter paper in a Buchner funnel. A flat-ended rod is used to compress the cake of paper residue in order to express as much extract as possible.

The volume of extract shall be measured and the residual cake weighed (W).

The extract shall be returned to a flask similar to the extraction flask and evaporated to dryness in a hot water bath; contamination is prevented by a large beaker (approximately 250 cm^3) suspended inverted over the flask.

When completely dry, 20 cm^3 de-ionized water shall be added to the flask and the drying repeated.

The extract residue shall be dissolved in 5 cm^3 10% HNO_3, transferred to a 100 cm^3 beaker and the flask twice washed out into the beaker with 5 cm^3 quantities of acetone.

The chloride content of the extract shall then be determined potentiometrically using a magnetic stirrer, glass reference electrode and silver wire indicator with a measuring device, e.g. a pH-meter.

The titrant shall be a solution of $AgNO_3$ of 0.02 M added in 0.01 cm^3 quantities from a micrometer syringe through a glass needle dripping into the titration cell.

Titrate a reagent blank consisting of the following: $(340 - W)$ cm^3 of water evaporated to dryness, 5 cm^3 of 10% HNO_3, and 10 cm^3 acetone.

14.4 *Results*

The chloride content of the extract solution shall be expressed as the mass of chloride ion, in ppM of the mass of the paper, and shall be calculated as follows.

$$\text{chloride content (ppM)} = 35.46 \, \frac{(A - B)\,\mathrm{M}}{D} \times \left(1 + \frac{W - D}{V}\right) \times 10^3$$

where.

M = molarity of the $AgNO_3$ solution

D = mass of the dried paper (g)

A = cubic centimetres of $AgNO_3$ solution used to titrate the extract

B = cubic centimetres of $AgNO_3$ solution used to titrate the blank

W = mass of wet paper residue (g)

V = volume of extract (cm^3)

The result is the central value of the three determinations.

Method 2

14.5 This method deviates from Method 1 in the following details:

- Four grams of paper are treated in 100 cm^3 of water instead of 20 g in 300 cm^3.
- Vigorous boiling is carried out for 60 + 5 min
- Treatment of the extract is as follows:

  Filter or decant the cooled extract solution and weigh 25 ± 0.1 g into a 200 cm^3 tall-form beaker Add 125 cm^3 of acetone and 15 drops of 1% nitric acid.

  Place a stirring rod into the beaker, then place the beaker on the magnetic stirrer and adjust the stirring speed so that the surface of the liquid is not broken.

  Immerse the electrodes in the liquid and allow the meter to stabilize, then start titrating.

  From the microburette, add 0.0025 M $AgNO_3$ solution in 0.01 cm^3 increments and record the change of potential in millivolts.

  Titrate to an end-point that represents the point of the greatest change in potential, or to a fixed point that has been previously determined from a potentiometric curve.

  Record the total cubic centimetres used to reach the end-point.

  Duplicate titrations should be run on each extract and should check to ± 0.01 cm^3 Duplicate specimens should check within ± 5% except at low levels where the differences may be greater, that is below 2.0 ppM

  Titrate a reagent blank consisting of the following. 25 ± 0.1 g of water, 125 cm^3 of acetone and 15 drops of 1% HNO_3

14.6 *Results*

The chloride content of the extract solution shall be expressed as the mass of chloride ion in ppM of the mass of the paper and shall be calculated as follows

$$\text{chloride content (ppM)} = 35.46\ \frac{(A - B)\,\mathrm{M}}{D} \times 4 \times 10^3$$

where.

A = cubic centimetres of 0.0025 M $AgNO_3$ solution used to titrate the extract

B = cubic centimetres of 0.0025 M $AgNO_3$ solution used to titrate the blank

M = molarity of $AgNO_3$ solution

D = mass of paper specimen (g) oven dry basis

The result is the central value of the three determinations.

15. Sulphate content

Under consideration.

16. Conductivity of organic extract

The purpose of this test is to determine whether or not ionizable organic materials are present in the insulating materials. Their presence is confirmed by the increase in conductivity of the organic (trichloroethylene) extract, and the test is considered to have particular significance when applied to insulating materials which are to be immersed in chlorinated coolants or impregnants.

Note — For precautions to be taken, see Note 2 to Sub-clause 12.2.

6.1 *Test apparatus*

A conductivity cell according to IEC Publication 247, Recommended Test Cells for Measuring the Resistivity of Insulating Liquids and Methods of Cleaning the Cells The measuring instrument shall be an electronic multi-megohmmeter using not more than 100 V d.c. or a sensitive galvanometer and battery.

The solvent is laboratory reagent grade trichloroethylene which has been purified by stirring in about 1% by weight of fuller's earth or another suitable material, e.g. silicon gel, and filtering through a sintered glass filter. A filter having a maximum pore diameter in the range 5 µm to 15 µm is suitable.

Note — Fuller's earth becomes ineffective if allowed to absorb moisture and may be dried by heating in clean air at a temperature not exceeding 120 °C

A blank test is carried out before each extraction and if the resultant conductivity consistently exceeds 5×10^{-4} µS/m the solvent is further purified until the conductivity is not greater than this figure.

Purified trichloroethylene is stable if kept in the dark or in a brown bottle, but its conductivity should be checked before use for an extraction.

During extraction and measurement, the solvent should be shielded from strong light, especially direct sunlight, and stored in the dark.

6.2 *Procedure*

One determination shall be made on each of three extractions. The extract is prepared by treating the material under test as described for conductivity of aqueous extract in Sub-clause 12 2 and the test pieces are gently heated in air for about 2 h at a temperature of 80 °C to 100 °C to remove any appreciable amount of absorbed water. The material is immediately transferred to a suitable flask and covered with purified trichloroethylene using a proportion of 1 g to 10 cm^3 of solvent. The solvent is gently boiled for about 1 h under reflux conditions using an all-glass apparatus constructed with ground-glass joints

At the end of this period, the flask is firmly stoppered and allowed to remain overnight in the dark. Any loss of volume through evaporation should be less than 10%

If not already known, the cell constant K is determined by means of an aqueous solution of known conductivity or by the capacitance method.

Before filling with the trichloroethylene extract, the cell is washed thoroughly with distilled water (if last used with an aqueous electrolyte), dried and cleaned several times with purified trichloroethylene. The cell is dried before filling and the transfer of the liquid from one vessel to another takes place in a stream of warm air to avoid risk of moisture condensing, resulting from cooling; it is necessary to avoid breathing on the electrodes.

The resistance of the extract is measured at a temperature of 15 °C to 25 °C, one minute after the application of the d.c. voltage.

If R is the measured resistance of the extract, expressed in megohms, and K is the cell constant (m^{-1}), then the conductivity of the extract, expressed in microsiemens per metre, shall be $\frac{K}{R}$ − conductivity of the solvent, expressed in microsiemens per metre.

16.3 *Results*

The conductivity of the extract of the material is expressed in microsiemens per metre.

The central value of three determinations is taken as the result; the highest and lowest values are reported.

17. Dissipation factor of organic extract

Under consideration.

18. Air permeability

The air permeability (π) of paper is defined by the formula·

$$\pi = \frac{V}{A\,t\,p} \left[\frac{\text{cm}^3}{\text{cm}^2 \cdot \text{s} \quad \text{kPa}} \right]$$

where V is a volume of air, expressed in cubic centimetres, passing through a sheet of paper with an area of A cm^2 within a time of t seconds under a constant air pressure difference of p kPa. For instruments which are used to measure the middle ranges of air permeability, ranging from 0.01 to 5 units, a pressure differential of approximately 1 kPa (98.1 mm water column pressure) is normally used.

For papers with lower ranges of air permeability, down to 0.0001 units, instruments with pressure differentials over the specimen of up to 3.5 kPa can be used, while for high permeability papers, ranging up to 2 × 10[illegible] units, e.g. electrolytic papers, pressure differentials down to 100 Pa can be used. These pressure differentials may be specified, for particular paper qualities, in Part 3

18.1 *Test apparatus*

The apparatus shall comply with the following requirements:

18.1.1 The volume shall be measurable to an accuracy of ±2% of the measured value and the time to within ±1% of the measured value and the rate of flow to an accuracy of ±5%.

18.1.2 The initial pressure differential over the test piece must be known to ±2% and shall not deviate by more than 5% during the measurement.

18.1.3 The test piece shall be clamped with an airtight gasket on the pressurized side of the test piece. This gasket shall not deform to such an extent that the testing area of the test piece is changed by more than 1%.

18.1.4 The testing area of the test piece shall be not smaller than 6 cm². An area of 10 cm² is recommended.

18.1.5 When water is used as a displacing medium, the air flow passing through the test piece shall be in such a direction as not to have been previously in contact with the water.

18.1.6 The air leakage shall be checked by clamping a hard impermeable material, e.g. a metal foil, in the apparatus in place of the test piece. Any leakage shall be less than 0.025 times the minimum air permeability measurable with a particular instrument.

18.2 *Test pieces*

The test specimen shall be conditioned according to Sub-clause 1.3. Not less than five test pieces shall be cut from the test specimen; the minimum size of the test piece shall be such that the piece protrudes noticeably in all directions from the clamping unit and provides the testing area required by Sub-clause 18.1.4.

18.3 *Procedure*

The details of the procedure are dependent on the apparatus being used, but it is essential:

1) to calibrate accurately the pressure differential to be applied over the test piece;
2) to ensure steady movement of the cylinder or device controlling the flow of air immediately before and during the time the determinations are being made;
3) to ensure absence of vibration which could affect the air displacement;
4) to ensure that the test piece is clamped uniformly without distortion;
5) to ensure that the measurements are made with the apparatus on a level surface.

18.4 *Results*

The results shall be corrected to an air pressure of 1 kPa by the formula in Clause 18. The central value obtained by testing five test pieces is taken as the result. The highest and lowest values are reported. Report the nominal pressure differential over the test piece.

19. Water and oil absorption (Klemm method)

19.1 *Test apparatus*

A shallow dish containing distilled water or oil.

The oil used shall conform to the requirements of the mineral oil of Class II, as defined in IEC Publication 296, Specification for New Insulating Oils for Transformers and Switchgear.

19.2 *Test specimens*

Cut ten test specimens, 25 mm in width and at least 125 mm in length, five being cut parallel with the machine direction of the paper and five cut parallel with the cross direction of the paper.

19.3 *Procedure*

Protect the apparatus against draughts. Suspend the specimens vertically, with one end dipping 6 mm in distilled water (oil) at room temperature, and after 10 min note the rise of the water (oil) in the specimen above the level of the water (oil) in the container. Record the height of absorption to the nearest 1 mm for each direction.

19.4 *Results*

Report the central value, expressed in millimetres, of each series as the water (oil) absorption of the paper in the machine and cross directions respectively, as well as the highest and lowest values of each series.

20. **Oil absorption (modified Cobb method)**

In this test, oil is applied to a known area of one side of a pack of papers. After a definite time interval the oil is poured off, the top sheet is blotted and the increase in weight through absorption of the oil is determined by direct weighing. The test is derived from a test for water absorption given in ISO Standard 535: Paper and board — Determination of water absorption — Cobb method.

20.1 *Test apparatus*

The apparatus for this test is shown in Figure 2*a*, page 25, and consists of a hollow metal cylinder having an internal cross-sectional area of 100 cm^2 and a height of about 50 mm. The cylinder is sealed to a bottom plate and is provided with a cover plate consisting of a sheet of oil-resistant rubber of sufficient size to cover the cylinder and bonded to a metal plate.

The cover plate is provided with means of clamping it into the base plate. The thickness of wall of this cylinder is not important, but can conveniently be about 6 mm. The IRH (International Rubber Hardness) of the oil-resistant rubber sheet shall be not less than 65. The top edge of the cylinder shall be machined smooth.

A fixture shall be provided which will secure the apparatus to the bench.

Figure 2*b*, page 25, gives the requirements for converting the Cobb absorbency tester used for the Cobb test for water absorption given in ISO Standard 535.

20.2 *Test pieces*

A test piece comprises a pack of paper sheets each 130 mm × 130 mm; the number of sheets is to be determined experimentally and is to be at least one more than the number penetrated by the oil Five test pieces are required for each of two series, the first series being carried out with one side in contact with the oil and the second with the other.

Care should be taken when assembling a pack to ensure that none of the sheets is inverted, i e. all the sheets should have the same side uppermost

20.3 *Procedure*

The oil used will be Class II, in accordance with IEC Publication 296 and should be stored prior to use in a sealed container maintained at the conditioning temperature. Use 100 cm^3 of oil in each test, but after the first test it is sufficient to top the oil up to the required level.

Maintain the temperature of the cell and the oil at the conditioning temperature. Determine the mass of the test piece.

Pour 100 cm^3 of oil into the test cell and place the test piece over it so that the oil contacts the "top" side of the paper when the cell is inverted. Insert the cover plate and screw down the wing-nuts tightly.

Invert the cell and allow the oil to soak into the paper for 45 s, then return the cell to its original position in a fixture which holds it to the bench and allow a draining time of 10 s.

Loosen the wing-nuts and withdraw the test piece from between the body of the cell and the cover plate slowly and continuously by pulling on two corners. Withdrawal should be completed in about 10 s and care should be taken to ensure that the lower surface of the test piece remains in contact with the front edge of the cell.

Lightly blot the top sheet to remove surplus oil and examine it visually to ensure that this has been achieved. Complete the blotting in not more than 10 s.

Determine the mass of the oil-impregnated test piece and note the number of sheets penetrated. Test all five test pieces in this way.

Repeat the above procedure with the opposite side of the test piece in contact with the oil.

20.4 *Results*

Express the oil absorption as the increase in mass in grams per square metre of the circular area exposed to oil and give the central value of five results in each test series. A single divergent reading differing by more than 20% from the central value shall be excluded from the calculation. If two such divergent readings are obtained, a further five tests shall be made.

If additional divergent readings occur, all ten readings shall be included in determining the central value and the oil absorption of the paper shall be reported as variable.

The oil absorption of the paper is the lower of the two results obtained from tests made on opposite sides of the sample pack.

21. Electric strength

The test shall be carried out in air in accordance with IEC Publication 243, Recommended Methods of Test for Electric Strength of Solid Insulating Materials at Power Frequencies

21.1 *Test apparatus*

The apparatus shall be in accordance with Clause 5 of IEC Publication 243. The electrodes shall be in accordance with Sub-clauses 6.1 1 or 6.1.3 of that publication. The preferred electrodes are the 25/75 mm electrodes. The smaller electrodes shall be used only if the width of the material prevents the use of the large electrodes The faces of the electrodes shall be parallel and free from pits or other imperfections

21.2 *Test pieces*

All test pieces shall be sufficiently large to avoid flash-over

The required number of tests may be made on one test piece. Where more than one thickness is required to form the test piece, the number of superimposed layers shall be given in Part 3.

Where the temperature or humidity of the test differ from those of Sub-clause 1.3, the treatment of the test piece shall be given in Part 3.

21.3 *Procedure*

The application of voltage shall be in accordance with Sub-clause 7.1 of IEC Publication 243. Criterion of breakdown, see Clause 8 of that publication

Nine tests shall be made.

21.4 *Results*

The result shall be based on the measured thickness. The report shall be in accordance with Clause 11 of IEC Publication 243. The central value and the lowest value shall be reported in kilovolts per millimetre.

Notes 1. — For special papers, a more elaborate statistical evaluation may be required in Part 3.
2. — Tests using d c. and impulse voltages are under consideration.

22. Dissipation factor and permittivity of unimpregnated and impregnated paper

22.1 *Test apparatus*

22.1.1 A guarded bridge, as described in IEC Publication 250, Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulating Materials at Power, Audio and Radio Frequencies Including Metre Wavelengths, or equivalent instrument.

22.1 2 A 50 Hz or 60 Hz generator and a detector for use with the bridge, as described in IEC Publication 250. Alternatively, voltage may be supplied from a 50 Hz or 60 Hz main-network, using a transformer and variable-ratio auto-transformer. Another frequency may be specified.

22.1 3 One or more sets of guarded electrodes, according to IEC Publication 250, constructed of a metal having high thermal conductivity and not subject to distortion with repeated temperature cycling. The surface should be resistant to tarnishing.

The electrodes shall be of such dimensions that the capacitance to be measured will be within the range of the bridge. The gap between the guard and the guarded electrodes shall be as small as practicable

The electrode surfaces shall be flat within 0.125 μm and shall be maintained in good condition.

For the testing of impregnated paper, the bottom electrode shall be fitted with a rim approximately 10 mm high round the edge to retain the impregnating liquid.

A total pressure of 20 kPa (unless another pressure is prescribed in Part 3) is exerted on the test piece by addition of mass to the upper electrode.

In order to facilitate removal of moisture from the specimen when testing unimpregnated paper, a series of holes may be drilled nearly through the upper electrode from the top side and completed through the electrode surface by means of a 400 µm drill. The holes shall not be obstructed by any mass added to the upper electrode. To avoid problems in cleaning, drilled electrodes are not recommended for testing impregnated papers.

22.1.4 Vacuum-drying equipment consisting of a suitable container, provided with means for bringing measuring leads out of the chamber, a gauge for measuring the pressure and a vacuum pump capable of maintaining a pressure less than 2.7 Pa (0.02 torr).

22.1.5 Heating equipment that provides a means of heating the electrodes and specimens to the specified temperature.

22.1.6 A thermocouple embedded in the guarded electrode to indicate accurately the temperature of the test piece. A thermometer may be used if measurements show that it accurately indicates the temperature of the test piece.

22.1.7 Equipment to provide a means of introducing thoroughly dried air or a dry inert gas into the vacuum chamber, for example, a train including sulphuric acid and phosphorus pentoxide or activated alumina drying apparatus.

22.1.8 When applicable, impregnating oil in accordance with IEC Publication 296, unless another impregnating liquid is specified. Degassing and drying of impregnant are achieved by passing the required impregnant down through a column of glass beads at a temperature and vacuum sufficient to achieve drying and degassing without removal of the lighter fractions of the impregnant

22.2 *Test pieces*

Layers of paper at least 3 mm wider than the diameter of the guarded electrode

22.3 *Procedure*

One measurement only shall be made.

22.3.1 Cut from a roll sufficient layers to provide a stack of not less than 100 µm thickness plus two protecting sheets and prepare a test piece of the appropriate size. The two outer sheets are removed with tweezers and the remaining pad is carefully centered between the electrodes. The actual area under the electrodes shall never be touched with bare hands

22.3.2 Heat the specimen and electrodes to 115 °C, unless otherwise specified, simultaneously evacuating the chamber. Maintain 115 ± 5 °C and a chamber pressure of less than 2.7 Pa (0.02 torr) until the test piece is dry. It has been found that 16 h at these conditions is sufficient if the upper electrode is drilled to facilitate the removal of moisture, otherwise 24 h or more may be required The test piece can be shown to be dry by steady-state measurements of dissipation factor.

22.3.3 *Unimpregnated paper*

Switch off the heater, break the vacuum with dry air and measure the dissipation factor and capacitance while the specimen is cooling. The measurements are made at temperatures as close as possible to 115 °C, 105 °C, 90 °C, 70 °C and 55 °C. Make the measurements between 1.2 kV/mm and 1.5 kV/mm.

22.3.4 *Impregnated paper*

Switch off the heater, break the vacuum with dry air and measure the dissipation factor and capacitance at a temperature of 115 °C. Provided the dissipation factor is similar to the value obtained on an earlier test on similar test pieces conducted as in Sub-clause 22.3.3, the chamber is re-evacuated to a pressure higher than the vapour pressure of the impregnant at the test temperature, and sufficient degassed impregnant is transferred to the bottom electrode to allow the paper test piece to be fully immersed in the impregnant. The vacuum is broken after 10 min and measurement of dissipation factor and capacitance are made at temperatures as close as possible to 115 °C, 105 °C, 90 °C, 70 °C and 55 °C. Make the measurements between 1 2 kV/mm and 1.5 kV/mm.

Notes 1 — It is good practice to verify after the test that the impregnating oil is not contaminated

2 — This method is unsuitable for liquids of high permittivity, e g. askarels.

22.4 *Results*

The report shall include the following:

- curve of dissipation factor as a function of temperature,
- thickness of the test piece;
- permittivity calculated in accordance with IEC Publication 250,
- applied stress, expressed in kilovolts per millimetre;
- nature of the impregnating liquid, when applicable

23. Conducting paths

There are three methods available, the method to be used shall be prescribed in Part 3.

23.1 *Method 1*

This method is particularly appropriate for 100% inspection, where comparatively few failures can be expected.

23.1.1 *Test apparatus*

Electrodes: Two electrodes consisting of a smoothly machined cast-iron or other metal plate, and a set of smooth solid brass rollers (see Figure 3, page 26).

The plate dimension parallel to the direction over which the test specimen is moved shall be at least 150 mm; the other dimension of the plate shall be at least as great as the width of the test specimen.

The surfaces of the rollers shall be machined and polished to smooth cylinders. The finished dimensions of the brass rollers shall be as follows:

- diameter: 38 mm;
- width of face: 25 mm.

The rollers shall be mounted in two parallel rows above the plate electrode and so arranged that each roller may be raised above or lowered onto the plate surface, automatically aligning the roller surfaces with the plate surface.

The rollers and plate shall be adequately insulated from each other. The rollers shall be mounted so that continuity of electrical connection between them and the potential source is ensured when they are rotating. The two rows of rollers shall be mounted with their axes 90° to the direction in which the test specimen is moved. The rollers in each row shall be spaced 35 mm apart on centre lines, and the two rows shall be so placed that the midpoints of the rollers in one row are opposite the midpoints of the spaces in the other row as shown in Figure 3, page 26.

The total force exerted by each roller on the surface of the test specimen shall be not more than 3 150 N nor less than 2 450 N. A limiting resistance to avoid damage to the electrodes may be employed.

23.1.2 *Voltage*

The voltage shall be 2 V/µm r.m.s., unless otherwise specified in Part 3.

23.1.3 *Test specimen*

The test specimen shall be one of such width that its edges extend at least 25 mm beyond the outer edge of the adjacent rollers The test specimen shall be at least 7.5 m in length.

23.1.4 *Procedure*

Raise the rollers, insert the end of the test specimen and lower the rollers onto the paper surface. Connect the electrodes with a potential source of the proper voltage prescribed in Sub-clause 23.1.2. Draw the specimen between the plate and rollers at a speed of 10 m/min to 20 m/min. Count the number of holes burned through the specimen, each burned hole being considered a conducting path.

Instead of counting the number of holes burned, electronic counting may be applied.

23.1.5 *Calculation and expression of results*

a) Calculation· Calculate the number of conducting paths per unit area by dividing the number of failures counted by the total area searched, expressed in square metres

b) Test report: The report should mention:

1) the number of conducting paths per square metre;

2) the total area of paper tested

23.2 *Method 2*

A conducting path in this method has a resistance lower than 50 kΩ. The apparatus shall not indicate a conducting path when the resistance is higher than 60 kΩ

23.2.1 *Test apparatus* (see Figure 4, page 26)

a) Electrodes Two electrodes, one of which consists of a ground metal plate trued up flat, and the other of a solid ground cylindrical brass or steel roller with an insulating handle The dimensions of the plate should correspond to those of the specimens under test

The dimensions of the roller are as follows·

— diameter. 50 mm;

— maximum width: 50 mm,

— pressure exerted by roller, including handle 0 1 to 0.25 N/mm width of roller

Mechanical accuracy of roller and plate The results of tests made according to this method are greatly dependent upon the mechanical perfection of the surfaces of the plate and roller, if departures from the true form much exceed 0 0025 mm A departure of 0 025 mm is considered a large error Means for the attainment of this degree of accuracy, which is greater than that normally required in electrical instruments, are stated below.

The roller may be turned and polished in a lathe or, preferably, ground to size accurately. The diameter of the roller may be measured by a dial micrometer of suitable sensitivity, the roller being rested on a flat anvil (free from dust) and its diameter measured from the anvil to the highest point of the roller surface, using a rounded micrometer plunger of small radius of curvature.

Ensure that the diameter so measured does not vary by more than ± 0.0025 mm along the whole cylindrical length of the roller.

Ensure that the plate, preferably cast or rolled in one piece, is not less than 25 mm thick. If it is built up from thinner plates welded or sweated together, ensure that these plates are of identical material, to avoid warping by differential expansion. In either case, the plate is roughly machined to size and flatness, and then annealed by prolonged heating (say 24 h at 200 °C to 300 °C) to avoid subsequent warping. It is then ground flat to an accuracy of ±0.0025 mm, which may conveniently be done upon a surface grinder. If this is carefully done on a sufficiently accurate machine, further polishing is unnecessary, the required property being flatness rather than polish. If polishing is desired, it is carried out in accordance with optical technique, since ordinary polishing will destroy the flatness obtained from grinding. The flatness of the plate may conveniently be checked by placing a lamp behind the roller, with the latter resting on the plate (free from dust), and observing the line of light between roller and plate.

Note. — Engineered surface plates 0.4 m × 0.25 m have been used.

b) *Detector:* A measuring instrument feeding into a pulse counter which records a pulse whenever there is a resistance lower than prescribed. The recording shall be one unit per conducting path over the range of time for which the voltage is applied to the conducting path. The counting device shall be capable of making separate counts in the case of conducting paths which are 1 mm or more apart, in the direction of the movement of the roller

c) A protective resistor, the resistance of the total circuit shall be at least 50 kΩ.

d) A source of 110 ± 10 V, normally d.c.

Where desired, an earth connection to the circuit may be made to provide maximum safety.

23.2.2 *Specimens*

a) The specimen shall be large enough to cover the plate completely, the sheet of paper being held in place by weights. Several specimens may be tested

b) An area of at least 1 m^2 shall be tested.

c) It has been observed when testing thin papers that the specimens need to be handled with the greatest care.

They should not be touched with the hands, nor should they be placed on any surface other than that of the plate after being taken from the rolls

23.2.3 *Procedure*

Fix the specimen to the plate, making sure it is flat, by means of weights placed at the ends. Connect the plate to one terminal of the 110 V supply.

Connect up the roller, the detector and the resistor, such that the free end of the resistor may be connected to the other terminal of the 110 V supply. Pass the roller over the paper in parallel strokes, taking care to avoid overlapping, the speed being appropriate to the performance of the counting unit. Do not apply any extra pressure.

23.2.4 *Calculation and expression of results*

a) Calculation: Calculate the number of conducting paths per square metre by dividing the number of conducting paths counted by the total area searched, expressed in square metres.

b) Test report: The report should mention:

1) the number of conducting paths per square metre;

2) the total area of paper tested.

23.3 *Method 3*

Mercury electrode test — Dubilier method

23.3.1 *Precautions*

The test should be conducted in a clean atmosphere, preferably in an enclosure completely sealed, except for a supply of filtered air.

Because of the likelihood of contamination, the first six outer turns of the roll of paper to be tested should be discarded. Care should be taken that the test roll does not become contaminated by any airborne particles, nor come into contact with any dusty surface.

Mercury has an appreciable vapour pressure at room temperature and this vapour is toxic. Care should be taken to handle the liquid so as to avoid spillage and to ensure that personnel are not unduly exposed to mercury vapour. The top electrodes should be kept covered and pressure-sensitive adhesive tape has been found satisfactory.

The paper, after it has been tested by running between the electrodes, is contaminated with mercury and used specimens should not be allowed to accumulate in the working area. Care should be taken in the disposal of used specimens, which should be burned in an efficient incinerator with an adequately high smoke venting system.

Note. — Even when all these precautions are taken, accidents may occur with possible harmful effects on health and the environment. Consequently, this method is only for use in testing capacitor paper, where it is appropriate to have a method which will detect weak spots as well as conducting particles. When the test is made, it is to be under the control of a responsible individual fully informed of the dangers associated with the use of mercury. The hazards associated with using mercury should be fully appreciated, before the mercury electrode test is included in a national standard or national specification for capacitor paper. When included, adequate supervision should be required

23.3.2 *Procedure*

A sufficient length of paper to give a test area of 1 m^2 is passed horizontally between upper and lower rectangular electrodes, both of mercury, at not more than 50 mm/s (see Figure 5, page 27).

The electrodes are 4.8 mm in the direction of motion of the paper and are not more than 50 mm across the paper. They are suitably arranged to cover the desired width of paper without overlap and aligned (top and bottom) to a tolerance of 0 25 mm and their supports are separated by a gap of not greater than 0.05 mm.

The electrodes are connected into a circuit which operates a counter, capable of operating at a count rate of at least 25 units per second, when any one of the following conditions occurs for 10 μs or more.

1) the resistance between the electrodes falls to 2 kΩ;

2) the fault current to earth rises to a selected value between 0.5 mA and 1.5 mA;

3) the potential difference between electrodes is reduced to 2.5 V or less.

The potential difference between the electrodes is 10 V or 40 V, but other voltages may be used within the capability of the circuit.

Suitable arrangements are made for calibration of the circuit to ensure that these conditions can be met.

The spurious count level of the instrument should not exceed one unit in any period of 10 min when a piece of 0.012 mm polyethylene-terephthalate film is held stationary between the electrodes.

Note. -- An alternative test using electrodes consisting of conducting rubber may be considered for inclusion later.

24. Heat stability

The tests made before and after ageing shall be made after conditioning approached from the dry side. The ageing period and the temperature shall be specified in Part 3. The guidance of I EC Publication 216, Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Material, shall be followed.

24.1 *Internal tearing resistance*

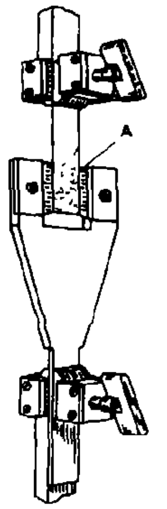
The heat stability can be expressed as the decrease in tearing resistance, determined in accordance with Clause 6 of this standard, after the heat treatment.

24.2 *Bursting strength*

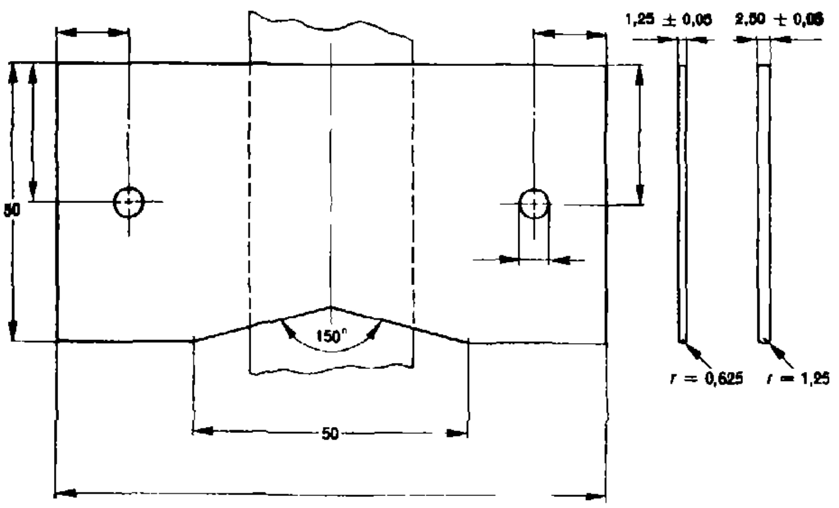
The heat stability can also be expressed as the decrease in bursting strength, determined in accordance with Clause 8 of this standard, after the heat treatment.

24.3 *Degree of polymerization*

The heat stability can also be expressed as the decrease in the degree of polymerization, determined in accordance with I EC Publication 450, Measurement of the Average Viscometric Degree of Polymerization of New and Aged Electrical Papers, after the heat treatment.



DETAIL A



Dimensions in millimetres

FIG 1 — Edge tear stirrup.

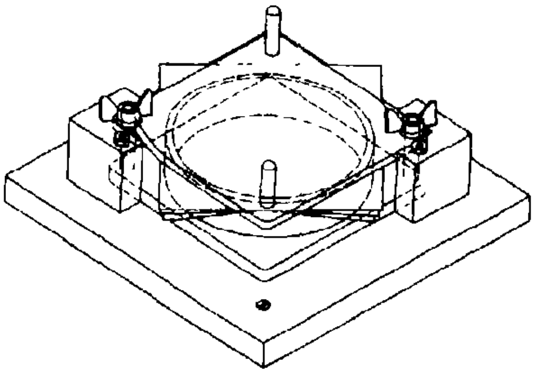
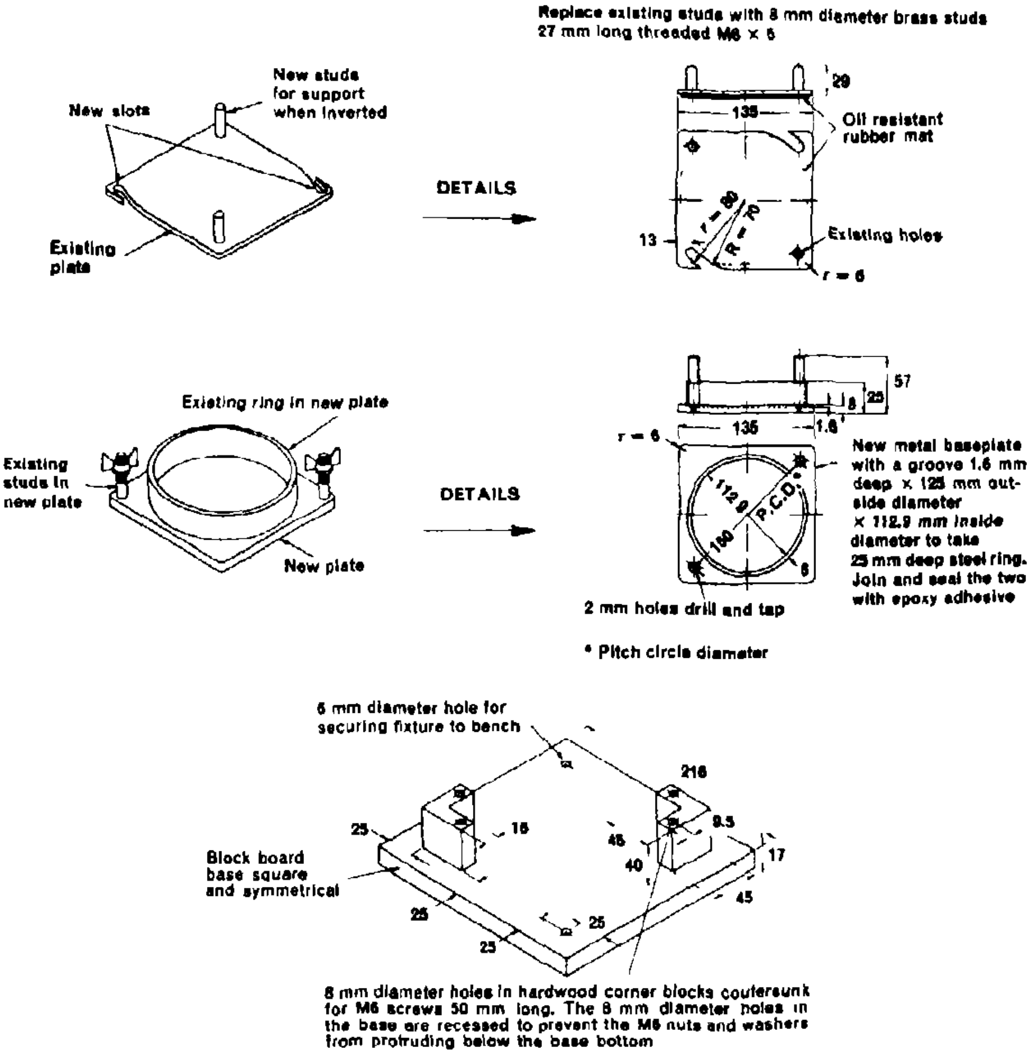


FIG. 2a. — Test apparatus for oil absorbency test



Replace existing studs with 8 mm diameter brass studs 27 mm long threaded M6 × 6

New metal baseplate with a groove 1.6 mm deep × 125 mm outside diameter × 112.9 mm inside diameter to take 25 mm deep steel ring. Join and seal the two with epoxy adhesive

* Pitch circle diameter

6 mm diameter hole for securing fixture to bench

8 mm diameter holes in hardwood corner blocks coutersunk for M6 screws 50 mm long. The 8 mm diameter holes in the base are recessed to prevent the M6 nuts and washers from protruding below the base bottom

Dimensions in millimetres

FIG. 2b. — Test apparatus for oil absorbency test (modifications required to Cobb absorbency tester).

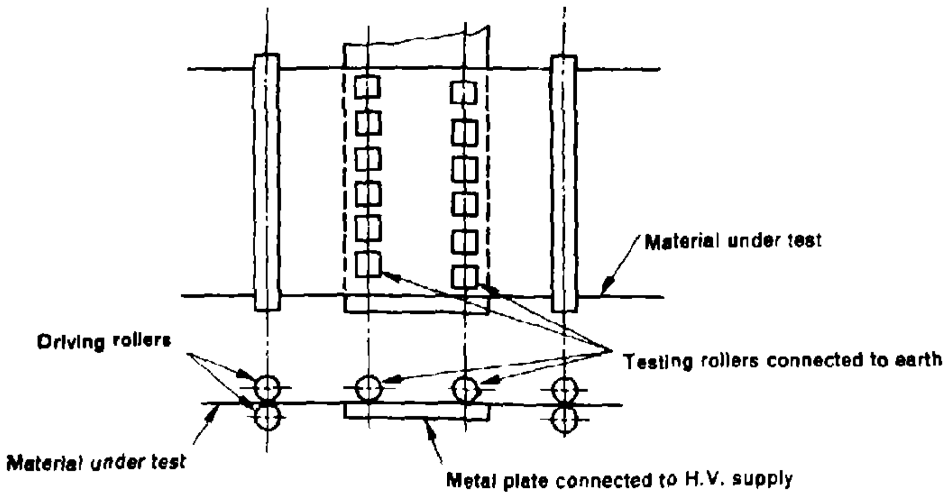
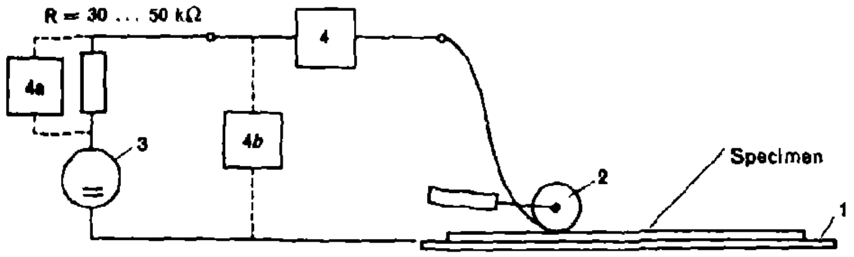
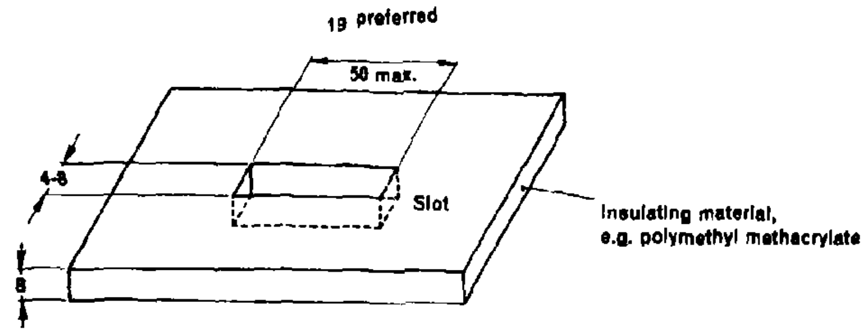

Material under test
Driving rollers
Testing rollers connected to earth
Material under test
Metal plate connected to H.V. supply

FIG. 3. — Diagrammatic arrangement of test apparatus for conducting particles.

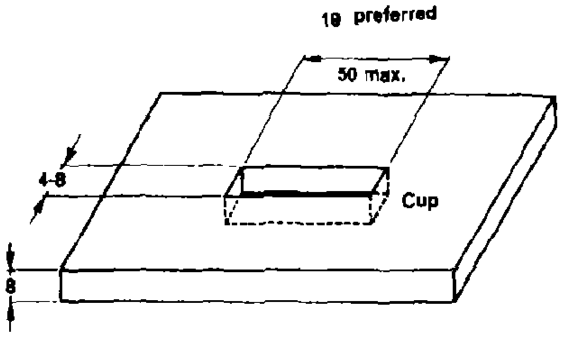


1 = plate electrode
2 = roller electrode
3 = source of 110 V
4 = indication and counter device
4a, 4b = alternative positions

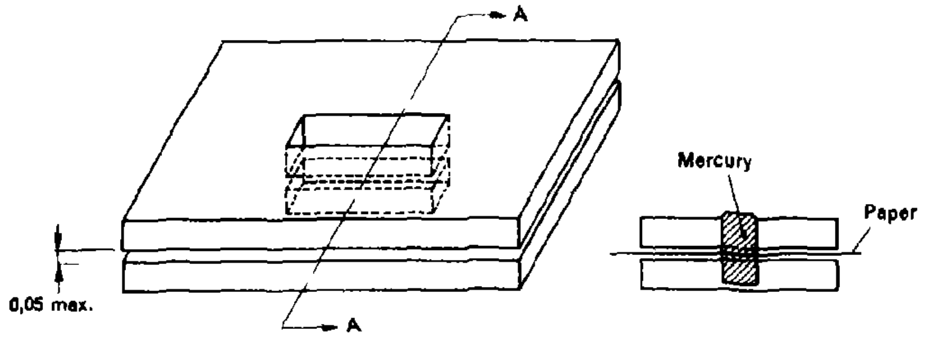
FIG. 4. — Test apparatus.



Top electrode



Bottom electrode



Assembly

Section AA showing electrodes with paper specimen

Dimensions in millimetres

FIG. 5 — Electrodes and assembly of mercury electrodes.

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CORRIGENDUM

Page 16

21 Electric strength

In the first line, instead of

IEC Publication 243

read:

IEC 243-1 (1988)

21.1 *Test apparatus*

In the first line, instead of

Clause 5 of IEC Publication 243

read.

Clause 7 of IEC 243-1 (1988)

In the second line, instead of

Sub-clauses 6.1 1 or 6 1 3

read

4 1 1.1 or 4 1 2

Page 17

21 3 *Procedure*

In the first line, instead of

Sub-clause 7 1 of IEC Publication 243

read:

9.1 of IEC 243-1.

In the second line, instead of

Clause 8

read·

Clause 10.

21 4 *Results*

Instead of

Clause 11 of IEC Publication 243

read·

Clause 12 of IEC 243-1.

Amendment No. 1

Page 17

21.4 *Results*

Amend existing Note 2 as follows

2 — A test using impulse voltages is under consideration

Complete Clause 21 as follows

21.5 *Test method using d.c*

21.5.1 *General notes on the test*

The electric strength should be measured in air, as far as possible according to IEC Publication 243: Recommended Methods of Test for Electric Strength of Solid Insulating Materials at Power Frequencies, since an adequate IEC publication for methods of test for electric strength using d.c. does not exist yet

21.5.2 *Electrodes*

Two cylindrical electrodes made from stainless steel (with a surface fineness of 2.5 µm or better) should be used. The faces of the electrodes shall be parallel and free from pits or other impurities. The edges shall be removed to give a radius of 3.0 mm.

The upper electrode should have a diameter of 25 mm and a height of 25 mm. The counter-electrode beneath should have a diameter of 75 mm and be approximately 15 mm in height and should be arranged coaxially, in accordance with Figure 1a of IEC Publication 243.

The counter-electrode connected with earth potential could also consist of a plane sheet of 40 µm to 50 µm thick aluminium-foil.

21.5.3 *Test pieces*

The test pieces should be large enough to prevent flashovers. Two layers of paper one upon the other are measured, except when otherwise specified in Part 3.

The test pieces should originate from one specimen. For example a sheet of 40 cm × 40 cm is taken from the paper and cut to two double-layered test pieces of 20 cm × 20 cm.

21.5.4 *Test procedure*

The test pieces shall be suspended or piled loosely in no more than 20 layers in a circulating air oven and shall be dried at 105 ± 2.5 °C for 60 min. They are tested within 1 min of removal from the oven. In case of dispute the test shall be carried out inside the oven.

21.5.5 *Number of measurements*

A minimum of nine breakdowns is carried out. When the lower 95% confidence limit on the test results is required, 20 breakdowns or more are to be made. The lag of the measuring instrument should not exceed 1%.

21.5.6 *Measuring procedure*

The tension is to be increased from about one-half of the expected breakdown voltage to breakdown in 5 s to 10 s. The appropriate breakdown value is found by two previous tests.

For paper with nominal thickness of ≤25 µm, the tension is increased by 200 V/s to 300 V/s until breakdown. At breakdown, that is to say when the short-circuit current has reached 0.1 mA to 1.0 mA, the voltmeter should continue to indicate the breakdown voltage.

Note — The short-circuit current is limited to 0.1 mA to 1.0 mA (in order to avoid damage to the electrodes) by insertion of a protective resistor in series with the test piece.

21.5.7 *Evaluation*

The report shall include the following:

1) *Thickness of the double layer of paper*
2) Type and size of the electrodes.
3) Number of breakdowns.
4) Central value.
5) Minimum and maximum value.
6) Electric strength (MV/m = kV/mm), calculated from the central value divided by the thickness of double-layered paper.
7) Where the lower 95% confidence limit is required (≥20 measurements):

$\bar{x}$ = mean value,
SD = simple standard deviation,
L_{LC} = lower confidence limit = $\bar{x} - (SD\ 1.64)$.

Amendment 2

Page 4

Sub-clauses 2.1 and 2.2

Add to the first paragraph:

The static load to be applied shall correspond to a pressure of 100 ± 10 kPa.

Amendment 3

Page 14

19 Water and oil absorption (Klemm method)

Replace this clause by the following new clause:

19 Rate of water absorption (wicking)

19.1 *Principle*

A strip of the material to be tested is suspended vertically with one end immersed in water The capillary rise in a given time is a measure of the absorbency of the material. The test is carried out in an enclosed vessel to provide a moisture saturation at the laboratory temperature

19 2 *Reagent*

19.2 1 *Distilled or de-ionized water*

Drinking water shall be used only if it can be shown to give results in agreement with those obtained with distilled or de-ionized water. In the event of dispute, distilled/de-ionized water shall be used.

19.3 *Apparatus*

a) A transparent water container at least 250 mm in depth.

b) A combined lid and test-piece support, fitted with two adjustable distance pieces at least 200 mm in length.

NOTE - A suitable apparatus is shown in figure 6 and may be constructed from materials such as 6 mm clear acrylic sheets The distance pieces are pointed at the lower end and threaded to permit adjustment

c) A timer capable of indicating times up to 15 min to the nearest second.

d) A cathetometer or ruler having a graduated straight-edge at least 300 mm in length, capable of being read to the nearest 0,5 mm.

e) Suitable pegs or pins for attaching test pieces to the test-piece support.

f) Paper clips.

g) A pencil.

h) A straight-edge.

19.4 *Conditioning*

Condition samples according to 1.3.

19.5 *Test pieces*

Cut ten strips (15 ± 1) mm wide and at least 200 mm long from the sample in the machine direction and, if required, a further ten strips in the cross-machine direction.

NOTE - In cases where a minimum test length of 200 mm is not available, e.g. laboratory hand sheets, the required length may be made up by joining the test pieces to an inert carrier In such cases, the length of the inert carrier should be specified and included in the test report

Draw a pencil line across each test piece at a distance of (15 ± 1) mm from one end. Fix a weight, suitable to ensure that the test piece hangs vertically, midway between the line and the end of the paper (a paper clip has been found to be suitable).

19.6 *Procedure*

Place the water container on a flat level surface and add water at (23 ± 2) °C to a depth of (50 ± 5) mm. Maintain the temperature at (23 ± 2) °C throughout the test. Place the lid on the container and adjust the distance pieces so that the points just touch the water surface.

Remove the lid from the apparatus and lay it on the working surface with the distance pieces horizontal Place a straight-edge across the tips of the points of the distance pieces and lay each test piece in position with its pencil line along the straight-edge. Fix the test piece to the lid by a pin or peg through one of the holes provided. It is convenient to test five test strips at a time

When all of the test pieces are fixed in position, replace the lid on the water container so that the weighted ends of the strips are immersed in water up to the 15 mm pencil line and immediately start the timer.

After 10 min ± 5 s remove the lid with the strips and lay the assembly on the working surface. Within 10 s of removal from the water, draw pencil lines through the water fronts on the strips If the front is uneven, estimate the average position.

Measure the distance between the pencil lines to the nearest 0,5 mm.

NOTES

1 It may be convenient to vary the time of test but in all such cases the time taken should be reported.

2 The results may be affected by soluble elements in the paper or the board In order to reduce this effect as much as possible, fresh water can be used for each new series of tests

19.7 *Results*

Calculate the mean value of the ten results for each direction tested.

For absorbencies less than 20 mm/10 min, express the results to the nearest 0,5 mm.

For absorbencies equal to or greater than 20 mm/10 min, express the results to the nearest 1 mm.

Calculate the standard deviation of the test results for each direction tested.

19.8 *Test report*

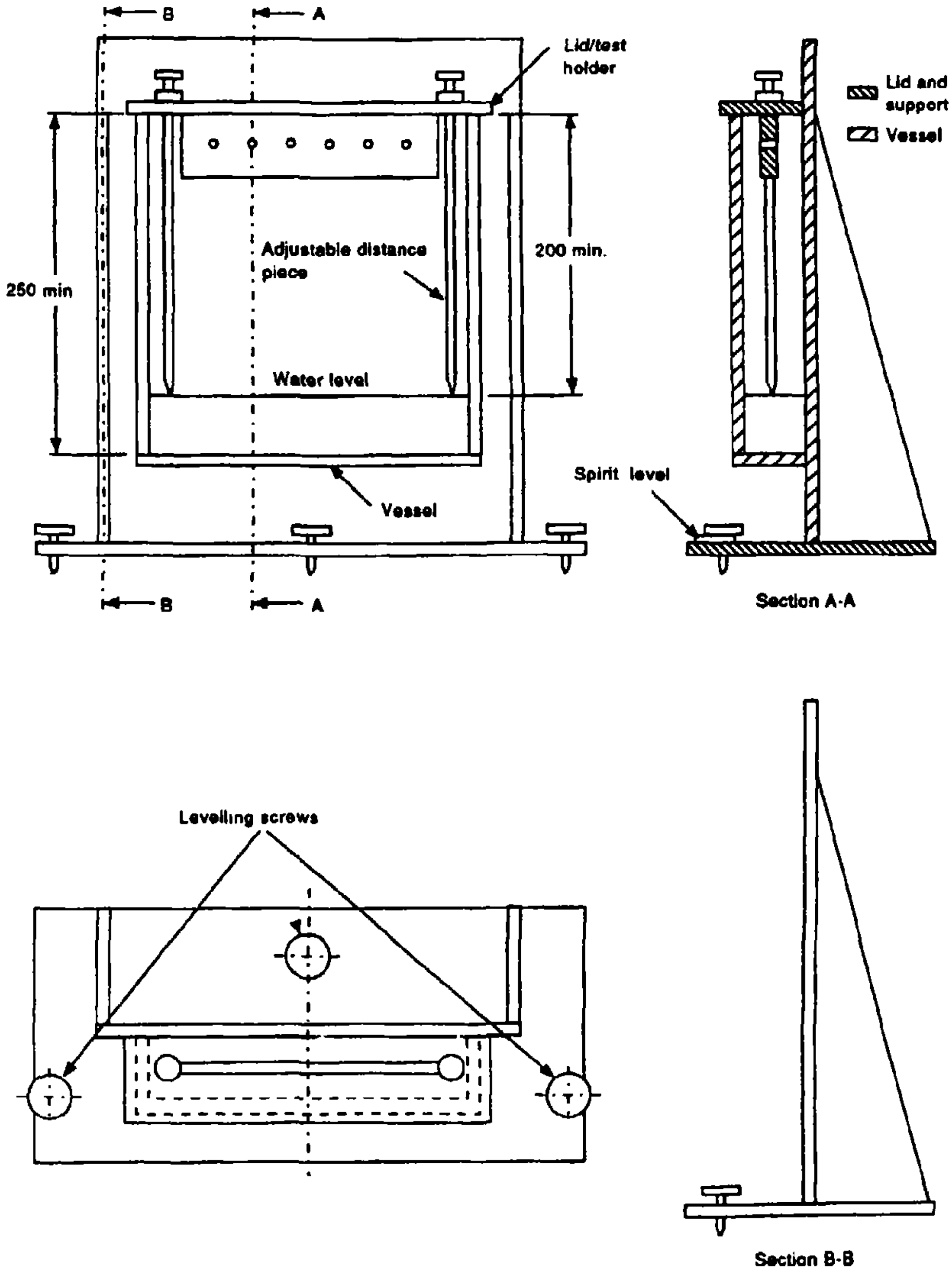
The test report shall include a reference to this standard together with the following information:

a) lengths of test strips and, if used, inert carrier;

b) mean and standard deviation of the machine direction water absorption value (Klemm);

c) if required, the mean and standard deviation of the cross-machine direction water absorption value;

d) any departure from this method, including time of immersion or other circumstances that may have affected the result



Dimensions in millimetres

Figure 6 – Klemm absorbency apparatus

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